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Review

Corrosion Protection Behavior of Carbon Nanotube-based Nanocomposite

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Abstract

Polymer coatings have been successfully employed in corrosion protection of metals. In this article, the polymer coatings containing carbon nanotube have been focused for anti-corrosion behavior. Epoxy-based coatings have gained significant research interest owing to sufficient hydrophobicity, conductivity, water transport behavior, and corrosion resistance. According to corrosion resistance studies, incorporation of nanotube may increase the corrosion resistance owing to filling of microspores prone to corrosion attack. The anti-corrosive polymer coatings with low nanotube content have shown enhanced surface hydrophobicity and anti-rusting properties in addition to strength, conductivity, and thermal resistance.

Keywords: Corrosion; nanotube; epoxy; microspores; coating

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1. Introduction

Corrosion has become a serious everyday problem of daily life and technical world. Initially, polymer and inorganic coatings have been used. However, pure polymer also corrodes under environmental conditions. Carbon nanotube (CNT) was first discovered by Iijima in 1991 [1]. The CNT own remarkable physical properties such as optical properties, mechanical strength, thermal stability, thermal conductivity, and electrical conductivity [2-5]. The polymer/CNT coatings have been employed in corrosion protection. These coatings have excellent wear, mechanical, and lubricating properties. However, there are various challenges in exploiting CNT in coatings due to poor wettability and formation of interfacial reaction products associated with the galvanic corrosion. For corrosion prevention, the polymer/CNT coatings have been formed using spraying, electrodeposition, sputtering, spin coating, dip coating, and several other facile techniques. For superior corrosion protection, uniform nanofiller dispersion within the polymer matrix is also essential [6, 7]. The polymer/CNT nanocomposites also has high chemical stability to improve the corrosion resistance [8-10]. The common methods for evaluating the corrosion resistance need to be explored in detail. In this review, polymers as well as polymer/CNT coatings in corrosion protection have been reviewed. Performance, applications, fabrication, and essential features of these polymers and polymer/CNT coatings have been addressed.

2. Corrosion protection

Corrosion is an inescapable phenomenon of metals and materials. Several methods have been employed, yet an ideal protection has not been discovered [11]. Iron is highly reactive towards environment (air/moisture) due to natural tendency to form iron oxide. However, thin layer of iron oxide on metal surface may prevent rusting at 99% RH. Contaminants such as acid rain may destroy the iron oxide layer and permits corrosion. Corrosion protective coatings can be organic, inorganic, metals, polymers, and other materials [12-15]. Initially, inhibitors, cathodic/anodic protection, and applying protective coatings have been used to slow down the corrosion. Corrosion resistant metals such as Au, Ag, Ni, Ti, etc. have also been used. Presence of corrosive medium oxidizes metal fastly and electrons flow to substrate, so makes it cathode. Organic coatings such as epoxy, polyurethane, and other polymers have been applied. Nanocomposite coatings have also been used for corrosion protection. The coatings will hinder corrosion by barrier formation between corrosive agent and the substrate. The polymers mixed with high nanoparticle contents renders better performance. Carbon nanotube (CNT) can also be incorporated in polymeric coatings to improve the mechanical, thermal, and wear resistance of these coatings [16-20].

3. Polymers in corrosion protection

Epoxy is one of the most common polymer used as barrier coating material [21-25]. This coating has been tested under moisture, chemicals, corrosive medium, and extreme marine environment. Cured epoxy structure consist of various functional groups such as amino groups, carboxyl groups, and hydroxyl groups. Due to the hydrophilic nature of these functional groups, epoxy has free electrons to attract water so decreasing protection for metals (Fig. 1). However, protectiveness of epoxy coatings can be improved by varying the coating thickness and surface behavior.

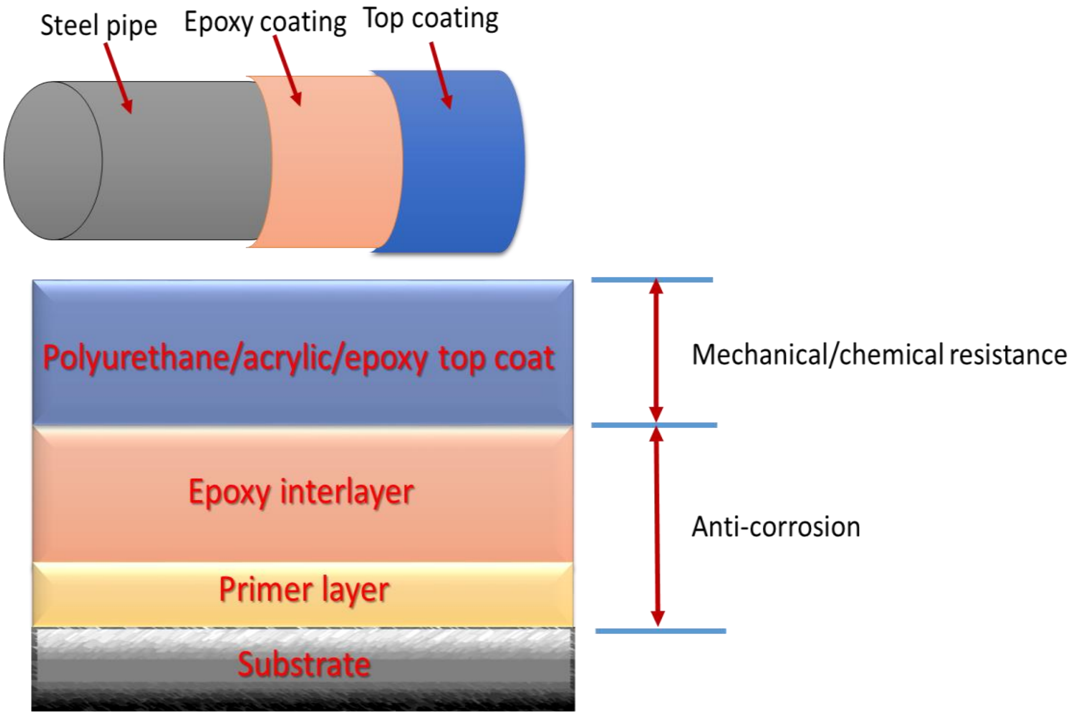

Fig. 1 Epoxy coating.

These coatings usually consist of three layers such as primer, main layer, and top coat. Conducting polymers have also been used as corrosion protective coatings. Polyaniline is also a corrosion resistant polymer. Fig. 2 shows anodic protection of steel with polyaniline. It is believed that the semiconducting properties of conducting polymers may prevent the corrosion of iron and its alloys [26-30]. Conducting polymer coatings have been used since the beginning of 19th century. Their main disadvantages of conducting polymer coatings are susceptibility to damage due to mechanical and thermal shock.

4. Carbon nanotube-based nanocomposite in corrosion protection

Organic coatings have been most commonly used for metal protection. They form physical barrier against corrosive species. Incorporation of nanocarbon nanoparticles may form conductive network in epoxy, which can be connected to the substrate. The nanoparticles may facilitate the cathodic protection against corrosion (Fig. 3). There have been efforts to increase the mechanical properties of coatings and corrosion resistance with adding small amount of nanofiller. The primer in these coatings may be made up of epoxy, inorganic particles such as zinc, or epoxy composites. Different polymers with CNT, graphite, graphene, and carbon black have been used in these coatings to improve the conductivity and prevent corrosion [31-40].

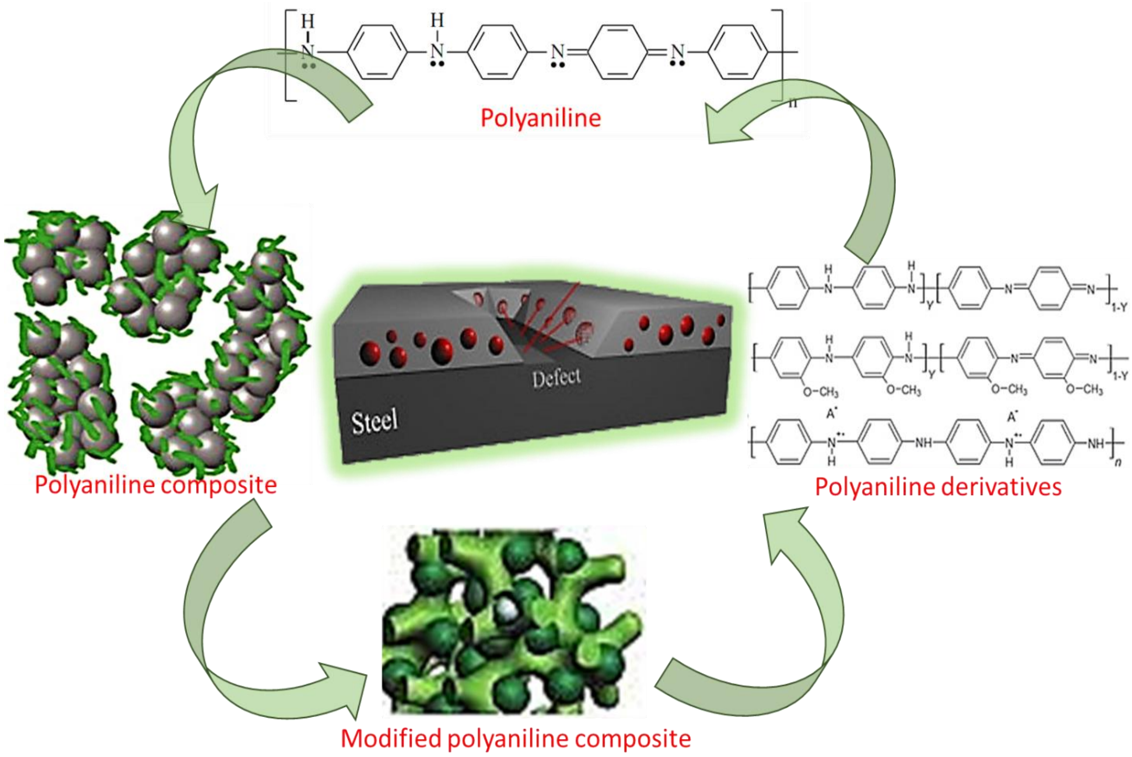

Fig. 2 Polyaniline coatings.

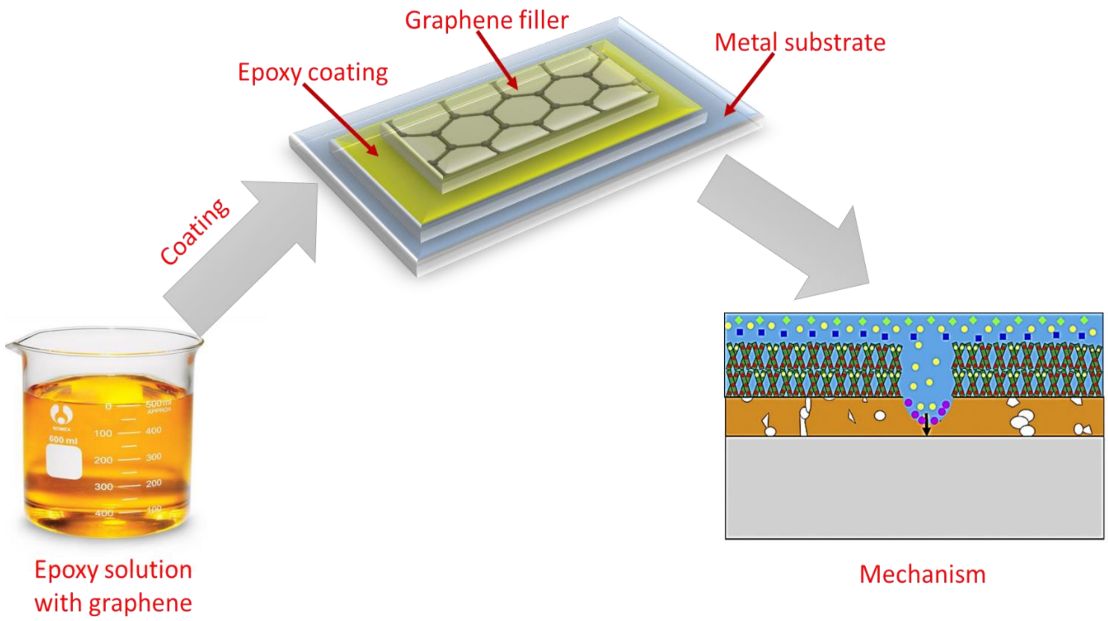

Fig. 3 Corrosion inhibition by nanocomposites

In polymer coatings, CNT nanofiller is chemically more active with superior mechanical and electrical properties and high percolation thresholds. Moreover, CNT may offer hydrophobic properties [41-46]. As epoxies are hydrophilic with chemical groups such as hydroxyl and carboxyl, so not suitable for corrosion protection applications alone. Therefore, using CNT in polymer coatings has attracted research attention [47-59]. According to electrochemical impedance studies, increasing

CNT content in coatings may improve pore resistance and reduce the ionic conductivity of polymers.

5. Conclusion

New promising polymer and nanocomposite coatings for corrosion protection have been developed. Application of CNT in nanocomposites and coatings has been researched for corrosion protection. The research generally revealed that the polymer/CNT nanocomposite has improved the corrosion resistance. The nanotube has ability to fill the gaps and coating defects, so promoting the passive layer formation. The CNT-based coatings have very low conductivity threshold, high electrical conductivity, thermal stability, and high mechanical properties. To evaluate the effect and realizing the corrosion mechanism, future studies are needed. Functional nanotubes can also be reinforced in polymers to form high performance anti-corrosion coatings.

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